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SCIENCE

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ACADEMIC EFFICIENCY[1]

ABOUT ten years ago I was asked by the president and general manager of a large manufacturing corporation to advise him how to improve the performance of his boiler house. During the previous winter it was pushed to its utmost to deliver enough steam to run the engines and to keep the buildings warm, and the next winter, on account of extensions to the factory and increased output, the demand for steam would be still greater. Before beginning my work the president told me something of the history of the company, and of how he came to be the general manager. It had grown in fifty years from a small concern to a large one, occupying several blocks of ground. The business was the manufacture of a variety of shelf hardware. He had for several years been a director and the manager of the sales department, and on the death of the former factory manager the directors insisted on his taking the place, although, as he said, he knew nothing about running a factory. He started in to learn how by calling in the best outside expert advice available. He was paying $10,000 for a year's services of a highly skilled expert in machinery, jigs and methods of manufacturing, who was making a revolution in the shop, which amply justified the high price paid for his services. This man said he knew nothing about boilers, and therefore I was called in to tackle the boiler problem. Incidentally the president told me that the catalogue of the products made by the concern con-

[1] A paper presented at the Boston meeting of the Society for the Promotion of Engineering Education, June 28, 1912.

tained 14,000 items, each of which involved patterns, jigs, templates, storage, bookkeeping records and correspondence. Probably half of these items were either obsolete or in very small demand, and another large fraction were unprofitable to handle. Another $10,000 might have been properly spent in making a selection of which of the 14,000 items should be abandoned and in printing a new catalogue.

In regard to the boilers, the president told me I could get all information available from two men, the superintendent of the factory and the chief engineer, who were at loggerheads. One had told the president one story about the boilers, and the other an opposite story, and he did not know which one to believe. He called the superintendent into the office to tell me his story and, dismissing him, called in the engineer, who told me the other story. I then had the engineer take me through the whole factory, including the power plant. On my return to the office I told the president that the engineer had told the facts, and that the superintendent had not because he was ignorant; he knew nothing about a power plant and never would know, for his bump of conceit was too great to permit of his learning. I reported further that the trouble from lack of steam was not the fault of the boilers—there were about 25 of them, crowding the boiler house to its capacity, and there was no available land for an addition to it—they were making as much steam as they should be called on to make with due regards to economy of fuel; but the trouble was entirely owing to the great waste of steam throughout the factory in winter time. Live steam was used for heating, and numerous traps were wasting both steam and hot water. As a result of my investigation an exhaust-steam heating system was installed, and that stopped all complaints of the insufficient supply of steam.

This long story about a factory may seem to have nothing to do with academic efficiency, but there are several points of resemblance between its condition and that of some educational establishments. They, like it, are suffering from inefficient management continued through a long period of years; they have too many items in their catalogue; heads of departments at loggerheads; a board of directors who are capitalists, but who know nothing of the details of the business they are supposed to direct; a president and general manager who is well versed in the advertising part of the business, but knows nothing of the best ways of producing its product. The factory, however, has two points of difference from and advantage over the college. (1) The competition of its rivals forces it to improve its methods, while the college has no such stimulus to improvement. (2) The manager of the factory referred to knows that he knows nothing about the best way of running a factory and therefore calls in outside expert assistance, the manager of the college thinks he knows it all, and therefore has no need of advice.

I said some educational establishments, not all. There are others, and this brings me to another story. It is about a university.

A certain large university more than twenty-five years ago had an engineering college that was already suffering from dry rot although it was only about ten years old. It had a good location, excellent buildings and equipment, and ample funds, yet the college had lost prestige, and the number of students was decreasing. The president of the university knew nothing about engineering education, but he was wise enough not to pretend to know anything about it. He asked half a dozen or more consulting engineers and engineering professors to visit the college and independently to give him written reports as to

what ought to be done to improve the college. I was one of the visitors. I found that the college was divided into two independent departments, one theoretical and the other practical, each presided over by a professor who was responsible only to the president. I spent a morning with one of these professors and an afternoon with the other. Each told a tale of woe, about the utter worthlessness and total depravity of the other man. I advised the dismissal of both, and the appointment of a man who was big enough to be the head of the whole college. Some months were spent by the president of the university in getting these reports and in interviewing different experts, including men whose names had been suggested as qualified for the position. He selected the right man, gave him full authority, approved his every request, and the trustees gave him everything he asked for in the way of competent assistants and additional equipment. The theoretical professor resigned, and the practical one gracefully subsided into a minor subordinate position, where he gave no trouble. The college grew with great rapidity. In ten years it was in the front rank of the engineering colleges of the world, which position it still holds.

Note the points of similarity between the factory and the university as related in these two stories. Each was suffering from inefficient management, each had a president who was ignorant of the details of the business, but who was conscious of his ignorance and was willing to take advice from outside. In each case the advice was taken, with the best possible results.

My subject is entitled Academic Efficiency. I use this short term merely because it has been used before to mean the efficiency of educational methods, and it may be necessary to explain that the word academic here means relating to an academy or educational establishment, and not, as it sometimes means, "unreal" or "unpractical." The word efficiency is often used with different meanings. Dr. Eliot, ex-president of Harvard University, in his little book on "Education for Efficiency" defines it as "effective power for work and service during a healthy and active life" and he says:

> National education will be effective in proportion as it secures in the masses the development of this power and its application in infinitely various forms to the national industries and the national service.

The engineer uses a more restricted and technical definition, the quotient of output divided by input, or the relation or ratio of the result achieved to the effort in obtaining it. Mr. Harrington Emerson objects to this definition as insufficient in its not including an equitable standard of achievement or output as one of its factors, and defines efficiency as the "relation between an equitable standard and an actual achievement," or "the relation between what is and what could be."

Strictly speaking, the engineer's definition is limited to cases in which both the input and the output may be measured in the same unit, or in units that are convertible one into the other, such as foot-pounds and heat-units, but it is a convenient definition for many cases in which neither the whole output nor the whole input is capable of accurate measurement in similar terms. For example:

We spend or give (Input)	We get or gain (Output)
Time	Money or salable goods
Money or raw material	Health
Physical labor	Recreation
Mental labor	Education
Nervous energy	Satisfaction
Health	
Wear and tear of machinery	

If we take the engineers' definition expanded in this way so as to include in the

input every conceivable kind of expenditure and in the output every conceivable kind of achievement, it will apply to every activity of man. The efficiency, while it can not be stated in figures, as a percentage, is measured by the value of the output in relation to the input or expenditure. Thus a business man may spend every one of the items listed under the head of input, and measured by a money standard the result may show a high efficiency, but measured by a broader standard, in which the result as to health is a negative quantity, it is most inefficient. Then if he takes to golf playing he may spend time, money and physical labor, and gain health; the efficiency by the money standard is zero, but by the broader standard, including health, recreation and satisfaction, he may consider that the efficiency of the operation is 100 per cent.

A college spends all the items listed under "input," its efficiency is zero from the money standard, for its business is not to make money, and may be high or low measured in the other items listed under output. By Mr. Emerson's definition, the relation of an equitable standard to the actual achievement, or the relation between what is and what could be, we compare the actual output in health, recreation, education and satisfaction, with what might be realized under the best possible conditions of system and management. Are the results what they ought to be in kind, in quality or in quantity, and if they are not, what are the defects and how can they be remedied?

In the big factory of which the story has been told, the product included 14,000 items, many of which should have been abandoned, and much of the inefficiency was due to the factory's making products that should not have been made. When an efficiency expert begins his operations in a factory his first questions are what kind of product is made? Why is it made. Why not abandon it if it is not profitable? The same questions might be asked of a college. The next set of questions covers the quality. Is the quality too highly refined and too costly, so that its market is limited? Is it too common and cheap, so that it has to be brought into competition with the poorest goods on the market? Is it out of date and unfashionable? Is the quality what it ought to be, and if not what are the reasons, and how can it be improved? Surely these questions may be asked of a college, and it is the general belief that the answers would not be complimentary to the college. There are serious defects in the quality of the college product.

Next come questions as to quantity. Is the factory turning out too much of one kind of goods, so that the market is glutted and the price too low? Is it turning out too little, so that it is not doing as much business as it might do? Is it turning out too much of one kind and not enough of another; and if so, what changes should be made so as to establish a proper balance? Is the college overcrowding the professions with men who are not needed in them? Is it failing to supply the demand for the kind of men who are needed? The common opinion is that both of these questions must be answered in the affirmative. The last report of the Carnegie Foundation for the Advancement of Teaching says:

> In almost every state of the union there are more colleges in name than the country needs or can afford. They have been started without much regard to the ultimate educational demands—weak and often superfluous colleges. In many cases their existence makes impossible that of good high schools which would far better serve the educational interests of the community.

After these questions of kind, quality and quantity of product are considered, then comes the question of cost per unit of

product and of possible methods of reducing that cost. In the factory the solution of these questions is one of great difficulty and complexity. It includes the items of location, buildings, machinery, system of organization, functional foremanship, statistics, accounting, planning of work, routing it through the shop, methods of payment of wages, keeping high-priced men only on high-priced work and finally time study resolved into its elements, that is, motion-study. I quote from Frank B. Gilbreth's new book on Motion Study:

> There is no waste of any kind in the world that equals the waste from needless, ill-directed and ineffective motions. . . . Tremendous savings are possible in the work of everybody—they are not for one class, they are not for the trades only; they are for the offices, the schools, the colleges, the stores, the household and the farms. . . . It is obvious that these improvements must and will come in time. But there is inestimable loss in every hour of delay. The waste of energy of the workers in the industries to-day is pitiful. . . . In the meantime, while we are waiting for the politicians and educators to realize the importance of this subject and to create the bureaus and societies to undertake and complete the work, we need not be idle. There is work in abundance to be done. Motion study must be applied to all the industries. Our trade schools and engineering colleges can:
>
> 1. Observe the best work of the best workers.
> 2. Photograph the methods used.
> 3. Record the methods used.
> 4. Record outputs.
> 5. Record costs.
> 6. Deduce laws.
> 7. Establish laboratories "for trying out laws."
> 8. Embody laws in instructions.
> 9. Publish bulletins.
> 10. Cooperate to spread results and to train the rising generation.

Mr. Gilbreth refers to motion study of the industries that are producing material wealth, but his words may be applied to the industry of educating men and women, that is, to the schools and colleges.

The methods of reducing the cost per unit of product in industrial concerns have now been reduced to a science by the management experts, Taylor, Gantt, Emerson, Parkhurst and others. In educational circles only the merest beginning has been made. Bulletin No. 5 of the Carnegie Foundation for the Advancement of Teaching, a quarto pamphlet of 134 pages, entitled "Academic and Industrial Efficiency," contains a report by Morris Llewellyn Cooke of the investigation of the department of physics of eight different colleges or universities. Mr. Cooke has had several years' experience as expert on management of industrial works, and is now Director of Public Works of the city of Philadelphia. His report is only a preliminary one, and covers little more than a statistical investigation of the cost of instruction in physics per student-hour, and some observations on methods of administration, and on the economical use of buildings and of the time of the professors and instructors, in all of which he found great differences. The total cost of physics per student-hour at Harvard was $1.08 and at Wisconsin $0.60. Of these totals the interest on plant and equipment and administrative expense account is $0.53 at Harvard, and $0.18 at Wisconsin. There are differences in the colleges which are far more important, however, than those that can be expressed in dollars and cents. For example, Mr. Cooke found one in which the professors showed the heartiest interest in the progress of each individual student, and another in which "every time the students were mentioned, there were evidences that the teachers had in mind the students' scholarly inferiority and waywardness."

The cost per student-hour for any subject may be obtained as in Mr. Cooke's investigation. It will be a far larger task to determine the efficiency of the student-hour —that is, what return in valuable education

the student gets for the expenditure of the thousands of student-hours that he spends in college. We have as yet no standards of measurement by which educational efficiency can be satisfactorily measured, but it can not be doubted that some day such standards will be found, when well-qualified experts are employed to find them. For a method of obtaining such a standard in English composition, see the writer's paper in *Proceedings of the Society for the Promotion of Engineering Education* in 1907 on "An Experiment in Teaching English to Freshmen in a University."

Efficiency, according to the engineers' definition, is the relation of output to input, or the relation of the result to the effort and cost expended in achieving it. From the college student's standpoint, the input is four years of time and say $2,000 to $4,000 in money. The output is what he receives for that amount of time and money. Let us put what he receives in tabular form under two heads, life and study.

- Life
  - Acquaintance.
  - Companionship.
  - Fraternity.
  - Social activity.
  - Athletics.
  - Reading.
  - Leisure.
  - Travel.
  - Moral uplift.
- Study
  - Cultural
    - Disciplinary.
    - Information.
  - Technical
    - Foundations of Science and Art.
  - Vocational
    - Relating directly to life work.
  - Curious
    - Non-useful or dilettante.

How many hours out of the 24 in a day are student-hours, and how many are devoted to so-called college life? Is his time properly divided between the activities of life and study? Of the student-hours is there the proper balance between the cultural and the other branches? How and by whom is this balance determined? Which of the courses are prescribed and which are elective, and why? What text-books are used, and why? Are particular courses taught by the text-book and recitation methods, by the lecture and notebook method, by the problem method, or by the laboratory method? Is each teacher free to use his own method or is the method determined on by a department head or committee or by other authority? What experimental pedagogical work has been done to discover the relative efficiency of different methods? What are the results of such experiments? Have they been reduced to statistical form and published? What is the administration doing to improve educational efficiency? Is there any method employed to measure the relative efficiency of different teachers, or of the same teacher in different years or when using different methods? How are the tenures of office, promotion, salary, etc., determined? How are poor teachers got rid of or transferred to other positions in which they may be more efficient. What is the organization of the college, and what are the efficiencies of the board of trustees, the president, and the heads of departments? If an investigator like Mr. Cooke, or preferably a commission of investigators, were to report to the Carnegie Foundation answers to these questions after a year's examination of a dozen or more institutions of learning, it is safe to say that an appalling lack of efficiency would be disclosed. The commission would find every grade of goodness and of badness in the teaching staff, teachers generally overworked, underpaid and dissatisfied and on the lookout for positions elsewhere. It would find self-perpetuating boards of trustees responsible to nobody,

individual trustees chosen not for any educational qualification, but solely because they are men of wealth and influence; presidents chosen through personal or political favoritism, whose ideas of education are those of the middle ages, and whose methods of government are those of the tyrant. It would find the conditions mentioned by President Benton, of the University of Vermont, in his inaugural address, 1911, the election of new members of the faculty dependent entirely on the dictum of the president, "the administrative office a veritable cesspool where unpleasant experiences are deposited," "a coterie of professors painfully sycophantic in the presence of their lord and master and bitterly denunciatory of him when left to themselves," "reprehensible hypocrisy by those who teach," etc. President Benton seems to be unaware of the fact that the sycophancy and hypocrisy which he thus bewails are the inevitable results of government by an ignorant despot, and that they can be done away with only by a radical change in the system of government. I do not wish to be understood as believing that the conditions thus described are universal. There are many institutions in which there is no autocratic government, and in which the government approaches in some respect to democratic ideals, where free speech is possible, where merit is recognized and rewarded, and where the teaching methods are constantly being improved. Here and there we find evidences of attempts to find the best methods, and of new experiments in education whose results are very promising, for example, Professor Franklin's improvement at Lehigh in the method of teaching laboratory physics, the examination of the English teaching in different technical schools by Professor Earle of Tufts College, the introduction of the preceptorial system at Princeton, Professor Schneider's cooperative system in Cincinnati, the university extension work at Wisconsin, the investigation by a committee of the Society of American Bacteriologists of the teaching of microbiology, and Dr. Rumely's experimental preparatory school at Interlaken, Ind.

Mr. Harrington Emerson has written a book entitled "The Twelve Principles of Efficiency." He wrote it with especial reference to the efficiency of manufacturing establishments, but the principles may be applied to educational institutions. They are the following: (1) Clearly defined ideals. (2) Common sense. (3) Competent counsel. (4) Discipline. (5) The fair deal. (6) Reliable, immediate and exact records. (7) Despatching. (8) Standards and schedules. (9) Standardized conditions. (10) Standardized operations. (11) Written standard practise instructions. (12) Efficiency reward. The investigating committee might use this list of twelve principles of efficiency in its examination of the colleges and find to what extent they are in operation.

Suppose that the Carnegie Foundation were to have an investigation made such as is here suggested, what good would it do? The same good that Mr. Cooke's investigation of the cost of the student-hour did, and something more. It would call public attention to the subject, and might lead some universities to reform some of their methods. It would reveal how bad things are, which is the first step toward reform. The report would be denounced as Mr. Cooke's has been, by college presidents and by editorial writers of conservative ways of thinking, as utterly subversive of all the ancient educational ideals, and involving "a gross and fundamental error." But it would set men thinking. It would show them that some universities and colleges

and some educational methods are better than others, and give the public some knowledge which would enable them to select the best colleges, and some educators of a progressive turn of mind the information they are looking for in regard to methods.

The best possible result of such a report, however, might be that it might induce some multi-millionaire to think that he had a duty to perform in helping to improve the efficiency of educational methods, by contributing the funds that would be required to carry on an educational experiment similar in extent to the experiments carried on by Mr. F. W. Taylor in the Midvale and Bethlehem Steel Works. It required more than twenty years of labor and the expenditure of some hundreds of thousands of dollars to carry on his experiments on tool steel, which have revolutionized machine-shop practise, and on scientific management, which bids fair to cause a far more important revolution in all our industrial systems. Mr. Taylor's system of management can not be adopted without many modifications by an educational institution, but his system of experimentation can be. It is simply the careful collection of all the facts by an expert, their study by mathematical methods, the making of experiments to get more facts, their further study, and careful reasoning to arrive at correct conclusions. It takes years of time, thousands of dollars of money, and can only be undertaken with any probability of reaching valuable results by a scientific expert who is entirely unhampered by old traditions. The motto of the conservative is "whatever is is right," that of the scientific expert is, "whatever is is apt to be wrong; I am going to test it and find out whether it is right or wrong."

Here is the outline of an educational experiment to take ten years of time and cost half a million of dollars—less money, by the way, than one second-class university has spent on its equipment for athletics within a few years, and less than has been paid by some millionaires for a couple of paintings.

Appoint a commission of five well-educated men who are not connected with any educational institution, say a minister, a doctor, a farmer, a merchant and an engineer, to secure a wide diversity in points of view. Pay them $5,000 a year each for the first year, and a smaller sum in succeeding years, when their time will not be fully occupied, and provide them with an office, stenographer and clerk, and funds for traveling expenses. Let them spend a preliminary year in investigating actual educational conditions in this country, collecting facts, statistics and expert opinions, on which they should prepare a report. They should also report their opinion on what should be the course of education of a boy between the ages of 14 and 16, if he intends to go to work in the mechanical trades or in commerce at the age of 16, also what should be the course from 14 to 18 (1) if he intends to go to work at 18, (2) if he intends to enter a general college, (3) if he intends to enter a technical school. The second year the experiment is to be begun. Select a hundred boys who are ready to enter high school, of the majority of whom there is a reasonable probability that they will, if they prove fitted for it at 18, take a college course. Rent a preparatory school, or a portion of one, and have the boys taught, by selected teachers, in the courses laid down by the commission. Provide enough tutors or preceptors to insure that the education of the boys is properly supervised and that their time is not wasted. Continue their high school education, for as many of them as stay in school, for four years. During

all this time the commissioners are to be studying methods of high-school teaching, and methods of measuring the efficiency of teaching, preparing practical standards of examination, not merely to test the memory of the scholars, as in ordinary examinations, but to test their mental and bodily powers. Find out not only what the boys know, as a mere act of memory, but what and how they think, and what they can actually do. Test not only the hundred boys, or as many of them as remain, but also boys in other high schools, by the same standards or by other standards that may be proposed by the high school teachers. Cultivate the same spirit of emulation for success in scholarship that now exists for success in the athletic field, but give them also enough athletics and other recreation to develop their bodies as well as their minds. Train them also in hygiene, in morals and in manners, to make them not only scholars but gentlemen.

During these four years the commissioners are also studying college administration, courses, methods of teaching and efficiency, and determining standards of measurement of efficiency. When the boys are through their preparatory course of four years, send them to such colleges as have been selected for them, have them take the courses for which they are fitted, provide tutors for them and watch their progress through the college, testing them by predetermined standards in comparison with other college students. At the end of the four year college courses, the commission is to report on the whole eight years' experiment. It will be found that many mistakes have been made, but probably not so many as would be made in an ordinary eight years' course of high school and college. The success of the experiment is not to be judged by the success of these selected boys, but by the value of the information obtained and reported on by the commissioners as to the various methods of teaching and of college administration and by the acquirement of standards by which academic efficiency may be measured in the future.

During the whole of the eight years' experiment the boys should be required to keep a diary in which they record what seems to be the most important items concerning their education, and they should once a year present to the commissioners a written report of their progress, keeping a copy for their own future use. Four years after they have graduated from college, when their minds are sufficiently mature, they should be asked to write critical reports of their educational career as it then appears to them. A study of these reports by the commission, which should be continued in existence for that purpose, would no doubt furnish fruitful ideas for further educational progress.

Cecil Rhodes did a noble work in establishing the foundation of the Rhodes Scholarships in Oxford. Andrew Carnegie has done a grand work in establishing the Carnegie Institutes for Scientific Research and for the Advancement of Teaching. Equally grand will be the work of him who shall establish a foundation for the application of the methods of scientific management to the improvement of academic efficiency.

This proposed plan is merely a suggestion. There may be a better plan, but whatever it may be it will take years of hard work and a large sum of money to accomplish the desired results. It might be undertaken by the Carnegie Foundation for the Advancement of Teaching, by the Russell Sage Foundation, or by the government, but the funds of these foundations are probably already fully employed,

and judging by the past non-activity of the government in educational matters it might take twenty years of agitation before congress could be induced to make the necessary appropriation. The government has a Department of Agriculture which is making experiments for the farmer, to enable him to grow larger and better crops, a Bureau of Forestry which is trying to conserve our forests, a Bureau of Mines which is experimenting on improving the methods of mining and on the prevention of accidents. It has also a Bureau of Education, which publishes statistics of schools and colleges and some interesting papers on educational subjects, but which has never investigated academic efficiency or carried on an educational experiment. All educational reforms in this country have been originated by individual philanthropists or by individual universities. They do not come about by normal process of evolution in the educational world or by governmental action, with perhaps the single exception, the Morrill Land Grant Act of 1862, just fifty years ago. We therefore must look for a millionaire philanthropist to begin the great educational experiment which will lead to improving the methods of training our future citizens.

Our modern educational literature, addresses of college presidents, school superintendents, proceedings of societies, etc., all show the prevailing consensus of opinion that there is something seriously wrong with our whole educational system, and that instead of getting better it is constantly tending to grow worse. There exists also a great amount of ultra-conservatism and of mental inertia relating to the subject. It is high time that something practical be done in the way of reform.

William Kent

THE PROBLEM OF ORGANIZATION

II

THE PROGRAM

I have heard the title "philosophical biologist" applied to biologists who talk about such matters as this problem of organization. The honor is totally unmerited. The problem is in strictest sense a biological problem. No doubt philosophy is interested in its solution. Philosophy is and ever has been a field for speculation about unsolved biological problems. When biology and other natural sciences shall have solved all their problems, a considerable burden will have been lifted from the shoulders of philosophy. This helpful relation should, however, be a mutual one. Science will never solve its problems—at most, it will never do more than think it has solved them—unless it constantly realizes its own limitations and unless it frequently assures itself of the security of its foundations. Now, perhaps more than at any other time, the natural scientist stands in need of help which may well come from the philosopher. Is it not timely to raise the question as to the validity of the assumptions upon which science rests and the integrity of the methods by which we attempt to progress? Science is a tool by means of which the human mind seeks truth. This tool was not fashioned by some omniscient being and bestowed upon man for his use. He made it himself. Is it possible that the tool is now antiquated in its structure or so distorted and worn with long use that it no longer cuts true?

This problem of organization, in the sense in which I have stated it, is not only a biological problem. It is in a broad sense a physical problem. The materials of biological science consist of those substances which we call living, and the energies whose existence is revealed to us by the motions of the bodies composed of those sub-